Surface Water Risk Assessment For Dioxins and Furans From Chlorine-Bleaching Pulp and Paper Mills

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ABSTRACT

A surface water risk assessment was conducted to predict the potential human health and aquatic life impacts associated with 2,3,7,8-tetrachlorodibenzo-p-dioxin (2378-TCDD) and 2,3,7,8-tetrachlorodibenzofuran (2378-TCDF) discharged from chlorine-bleaching pulp and paper mills. Using 1988 effluent data, other site-specific information, and simplifying assumptions, it was concluded that predicted exposures could represent significant implications for human health and aquatic life near the mills.

INTRODUCTION

Numerous studies have confirmed the formation of chlorinated dibenzo-p-dioxins and dibenzofurans in the paper making process when chlorine is used as a bleaching agent for wood pulp. The U.S. Environmental Protection Agency conducted and coordinated a multi-media assessment of the problem of chlorinated dioxins and furans found in bleached wood pulp (paper contamination), effluent discharges, and sludge disposal. This study presents the exposure analysis and risk characterization of surface water discharges of dioxins and furans from 104 U.S. pulp and paper mills that use chlorine or its derivatives to bleach pulp.

APPROACH

Effluent data from samples collected in 1988 under the joint EPA/paper industry study (EPA, 1990a) were used in this assessment and provide a snapshot of the magnitude and locations of 2378-TCDD and 2378-TCDF releases to surface water.

The analysis focused on the highest in-stream contaminant concentrations immediately downstream of each mill discharge point, assuming fully-mixed conditions, steady-state conditions. Two approaches were used to estimate and compare exposures to 2378-TCDD and 2378-TCDF. The first was a simple dilution

calculation used to estimate the in-stream contaminant concentration after the effluent is mixed in the receiving water. The calculation assumes 100% of the in-stream contaminants are bioavailable to fish, and effectively includes exposure through uptake across the gills (dissolved form) as well as through ingestion of suspended solids (particulate form). The simple dilution approach was considered to represent an upper bound for bioaccumulation since a bioconcentration factor (BCF) based on dissolved contaminants was applied to particulate contaminants as well. The second approach used the water quality model, EXAMS II (Barnes et al., 1982), to partition in-stream steady-state water column contaminant concentrations between dissolved and particulate forms. Because no comprehensive studies exist for the build-up of these contaminants in sediments and bioaccumulation up the food chain, only the water column was investigated as a potential route of exposure and uptake of 2378-TCDD and 2378-TCDF by fish. Although food and sediment are the dominant exposure routes to fish downstream of the mills, the assumption that fish remain at the point of maximum in-stream concentration has a compensatory effect.

Receiving water stream flow rates for estimating long-term human health risks were calculated using the harmonic mean of historic flow measurements from nearby gaging stations. The lowest 7-day stream flow that occurs on a basis of once-in-ten years (7Q10) was used to predict short-term aquatic life impacts. These flows are EPA's best estimate of how to estimate exposure for long- and short-term effects, respectively.

Using water column concentration estimates from both approaches, edible fish tissue residue levels were estimated by employing a range of BCFs. BCFs of 5,000 (edible tissue) and 100,000 (whole body) were used for 2378-TCDD. The 5,000 BCF was derived from relatively short-term bioassays of 30 day duration (EPA, 1984). The 100,000 BCF was derived from recent laboratory studies performed by EPA's ERL-Duluth laboratory using exposure durations greater than 72 days. A single BCF of 3,900 (whole body) for 2378-TCDF was used and was based on relatively short-term tests. To estimate contaminant levels in the edible portion (for the BCFs based on whole body residue levels), the assumption was made that the edible portion was one-half of the predicted whole body residue level.

From fish tissue contaminant concentrations, average daily lifetime exposures were calculated based on national estimates of consumption rates for an average fish consumer, a recreational fisherman, and a subsistence fisherman (or other high rate consumer). An average consumer was assumed to

eat 6.5 grams/day of contaminated fish; this is the consumption rate used in EPA's water quality criteria documents (EPA, 1980). Rates of 30 grams/day and 140 grams/day were used to serve as consumption rates for a recreational and subsistence fisherman, respectively. These values are based on surveys conducted in the 1980s of recreational fishermen living in the west coast of the U.S. (EPA, 1990b). In the absence of readily available information on exposed populations, the risk assessment was conducted to predict risk to an individual consumer only, not to estimate incremental cancer cases that could occur in entire populations eating contaminated fish.

The assessment also considered non-cancer effects resulting from a single exposure to contamination of a relatively high dose. Based on studies conducted to assess the potential systemic effects (liver toxicity), EPA estimated a 1-day Health Advisory of 100 pg/kg/day for 2378-TCDD.

RESULTS AND DISCUSSION

The carcinogenic risk predicted varied depending on assumptions made for BCF, fish consumption rates, and whether bioconcentration occurred before or after particulate contaminants settled out of the water column. Table 1 presents the range of estimated cancer risks associated with human consumption of contaminated fish.

TABLE 1. Estimated Cancer Risk Associated With Consumption of Contaminated Fish.

APPROACH	CONSUMER TYPE	2378-TCDD BCF	RANGE OF CANCER RISK*
Simple dilution	Average	5,000	10^{-2} - 10^{-6}
	Recreational	100,000	10^{-1} - 10^{-6}
	Subsistence	100,000	10^{-1} - 10^{-6}
EXAMS II	Average	5,000	10^{-3} - 10^{-6}
	Recreational	100,000	10^{-1} - 10^{-7}
	Subsistence	100,000	10^{-1} - 10^{-6}

*Risks presented were calculated using toxic equivalence method: 2378-TCDD = 1, 2378-TCDF = 0.1; carcinogenic potency for 2378-TCDD of 1.6×10^{-4} pg/kg/d^{-1}

In terms of risks of non-cancer effects, the simple dilution approach estimates that discharges from 26 of the 97 mills evaluated (27%) could cause toxic liver damage from a single 115 gram serving, based on the Health Advisory of 100 pg/kg/day. Under the EXAMS II approach, only 9 mills of the 87 evaluated (10%) could cause these effects.

Aquatic life impacts were estimated based on a comparison of predicted

in-stream concentrations of 2378-TCDD and 2378-TCDF to preliminary chronic exposure level for the protection of aquatic life (0.038 pg/l for 2378-TCDD and 0.41 pg/l for 2378-TCDF). The simple dilution approach, using 7Q10 conditions, predicted that water column concentrations of 2378-TCDD immediately downstream of 80 of the 90 mills evaluated (89%) would exceed the chronic exposure level; 74 mills (82%) would exceed the level for 2378-TCDF.

Results indicate that, taking into consideration the effects of the assumptions and simplifications used in this analysis, there is a potential for high levels of 2378-TCDD and 2378-TCDF contamination resulting from surface water discharges from many of the chlorine-bleaching pulp and paper mills evaluated. These predicted contaminant concentrations could represent significant implications for human health and aquatic life.

Use of the simple dilution method resulted in higher estimated water column concentrations and greater human health risks than the EXAMS II method. This is because the simple dilution method assumed all contaminants in the water column, both dissolved and adsorbed to suspended solids, were bioavailable. In cases where the receiving water total suspended solids was relatively low, the simple dilution and EXAMS II results were comparable. When suspended solids were high, EXAMS II method estimated risks significantly lower than those predicted by simple dilution. Therefore, for those water bodies with relatively high suspended solids content, the EXAMS II method likely underestimated human health risks from consumption of contaminated fish tissue, since fish exposure to sediment-sorbed contaminants was not considered.

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